



DATELINE Los Alamos

U . S . D E P A R T M E N T O F E N E R G Y
U N I V E R S I T Y O F C A L I F O R N I A

NEW JET TURBINE WILL BOOST ENERGY EFFICIENCY

UNIQUE BLADE COOLING STRATEGY
AT THE HEART OF THE CONCEPT



Los Alamos researchers recently unveiled an innovative design concept for a jet engine turbine with the potential to significantly alter the world of turbine engines. The revolutionary design should be able to achieve better energy efficiency by being able to run at higher temperatures because of a unique turbine blade cooling strategy.

In jet aircraft engines, approximately 30 percent of compressor air is lost to secondary cooling needs to prevent meltdown of the engine. The new Los Alamos concept engine potentially eliminates this loss of efficiency as well. Before a prototype of the turbine can be built, the new design must be modeled. The Laboratory's powerful supercomputers easily can accom-

plish this complex modeling simulation. Los Alamos is looking for industrial partners to help develop this new turbine design.



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Advanced computer modeling of engines and turbines is an area where the Laboratory excels. In 1994 Los Alamos researchers helped General Electric's Aircraft Engine Division develop and validate a three-dimensional computer model of composite aircraft fan blades. For more on that work, see the June 1994 issue of *Dateline: Los Alamos*.

Over the past several years, KIVA, a three-dimensional computer code for the analysis of chemically reacting flows with sprays, like those found in engines, has been under development at Los Alamos. KIVA already has found widespread application and acceptance in the automotive industry.

The rewards of turbine research are many. A new jet engine turbine design providing as little as 1 percent improved energy efficiency could mean savings of hundreds of gallons of fuel per flight resulting in millions of dollars in annual savings for the airline industry and its customers. Other advantages, many in the area of national defense, include the development of advanced jet aircraft that could fly faster or farther on a single tank of fuel.

Researchers believe the new turbine design will have its biggest impact in conditions in which small turbines are used, rather than aircraft propulsion. For example, there is significant potential for use in the area of distributed power generation, in which small turbine engines are slowly being introduced as backup or replacement electrical power



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generators for business and industry. Electric power consumers also would likely benefit because any improvements to the electricity-generating turbines used by electric utilities should have significant economic and environmental rewards.

TURBINES THROUGH THE AGES



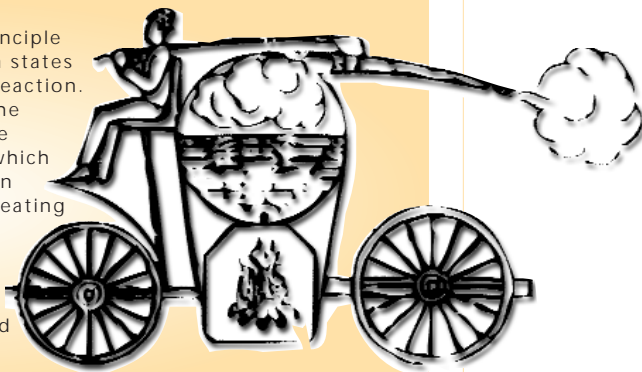
For more than 2,000 years humankind has sought to perfect the gas jet engine and the turbines they contain.

The history of the turbine begins in Egypt with Hero of Alexandria's discovery of jet propulsion in 150 B.C. Hero invented a rotated device placed on top of a boiling pot that was propelled by the effect of steam exiting several nozzles arranged radially around a hollow metal sphere. Hero called his invention an aeolipile. Although only a toy, the aeolipile proved to be an effective, if rudimentary, demonstration of jet propulsion.

A turbine is the technological marvel at the heart of a jet engine. Located downstream in the superheated confines of an engine's combustion chamber, the turbine is the result of decades of technological advances. These advances have made turbine engines some of the most efficient and reliable sources of propulsion and electrical power, but this efficiency comes at great expense.

Precisely formed by complex investment casting from expensive and exotic "super alloys," a turbine extracts energy from the fast-moving flow of burning fuel and compressed air. The turbine acts like a windmill in the center of this fiery flow of fuel and air. As the blades of the turbine turn, energy is generated to power the engine's compressor and fans that are used, in turn, to compress the air flowing into the front of the engine. The rest of the energy produced by the burning fuel is used to propel the plane or, in the case of turbines used in electrical power plants, to generate power.

In 1687 Sir Isaac Newton formulated the scientific principle behind Hero's machine. Newton's third law of motion states that for every action there is an equal and opposite reaction. In Hero's aeolipile, the jets of steam escaping from the nozzles are the action, the spinning of the sphere the reaction. Newton designed a jet-propelled carriage, which he called Newton's Wagon, to test this action-reaction principle. A water-filled sphere was heated by fire, creating steam that jetted from a large nozzle projected out from the sphere. As the steam escaped from the nozzle it was supposed to propel the wagon forward. It didn't — Newton's engine lacked sufficient power to move the wagon anywhere. Newton's Wagon lacked a turbine, but embodied the reaction engine.

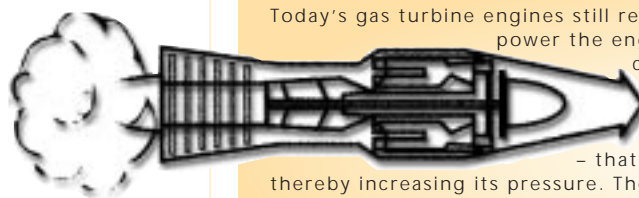




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Los Alamos scientists have long known that if turbine technology is to advance, new and innovative designs and materials must be developed that go beyond the current limits imposed by both metallurgy and the principles of aerodynamics.

The current generation of jet turbines, for example, requires precision forming of expensive alloys making them extremely complicated and expensive to manufacture. Because the environment in which they operate is harsh, even the highest quality turbines face limited lifespans caused by unforgiving heat and physical wear.



Today's gas turbine engines still rely on Newton's third law of motion, but use turbines to power the engine's compressor. The turbine is connected to the compressor by a rotating axial shaft. Air entering the engine flows parallel to this shaft moving through alternate rows of stationary and rotating sets, or stages, of fan blades – stators and rotors respectively – that are arranged to slow the air passing through them and thereby increasing its pressure. These compressors can increase the pressure as much as 25 times by the time it passes through 16 stages of fan blades.

Today, gas turbine engines are widely used for propulsion as well as for generating electrical energy. Hero and Newton would be proud.

Fundamentally, the higher the firing temperature in a gas turbine the more efficient it is. However, most of the metals used for jet engine turbines already have been pushed to their limits. Some turbine parts currently are being formed from large single crystals to achieve the highest possible melting points and maximum strength.

Most existing turbine designs incorporate extremely complex cooling and airflow strategies, but even these have their limits. Los Alamos' new turbine design incorporates a cooling strategy for the turbine nozzles and blades that allows the engine to run hotter, yet simplifies the engine structure.

Turbine research at Los Alamos is conducted in various disciplines. In the past, some of the funding has been provided jointly by the Department of Energy's Office of Industrial Technologies and the Office of Fossil Energy under the auspices of the Advanced Turbine Systems Program.

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JAPAN ENLISTS LAB SCIENTISTS TO STUDY ANCIENT COLORADO VOLCANO

RESEARCH WILL HELP IN CHOICE OF UNDERGROUND
NUCLEAR WASTE REPOSITORY

A study of a 34-million-year-old eroded, extinct volcano in southwestern Colorado will help the Japanese government choose a safe site for a future underground nuclear waste repository.

The recent eruption of Mount Usu near Date in northern Japan highlights the dangers posed by the complex plate tectonic setting in which the Japanese islands lie. One of the most tectonically and volcanically active areas on the Earth, Japan has more than 200 active or recently active volcanoes. And new volcanoes are known to form near the sites of existing ones.

Japan's three main islands provide limited land mass for a large population, making it difficult to find a site for safe geologic disposal of high-level radioactive waste, necessary to a country that intends to increase its reliance on nuclear power. To certify the safety of a repository for 100,000 years, the Japanese Nuclear Cycle Development



This is one of the main dikes of the Summer Coon volcano, with a natural arch known as La Ventana. The arch was formed by natural fractures within the dike. La Ventana is a popular recreation site.



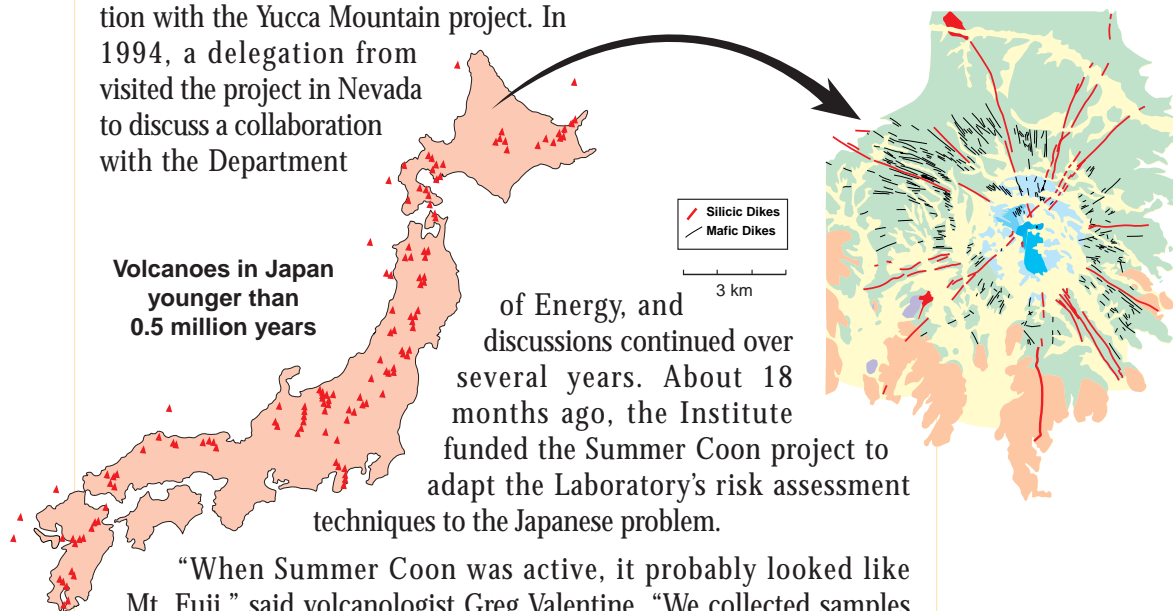
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Institute must understand the internal workings of nearby volcanoes and the range of their effects.

The completely exposed plumbing system of the Summer Coon volcano near Del Norte, Colo., in the eastern foothills of the San Juan Mountains allowed scientists from Los Alamos' Earth and Environmental Sciences Division to study effects for a volcano of similar size in Japan.

Laboratory scientists have been assessing volcanic risks for radioactive waste repositories since the late 1970s, in connection with the Yucca Mountain project. In 1994, a delegation from visited the project in Nevada to discuss a collaboration with the Department

**Summer Coon Volcano, Colorado
(32 million years old)**



of Energy, and discussions continued over several years. About 18 months ago, the Institute funded the Summer Coon project to adapt the Laboratory's risk assessment techniques to the Japanese problem.

"When Summer Coon was active, it probably looked like Mt. Fuji," said volcanologist Greg Valentine. "We collected samples that indicated that most of its activity occurred within a 200,000-year span, which is a good analog for the kinds of volcanoes in Japan."

All of Japan's dead and eroded volcanoes are covered by forest or broken by faulting, which prevents study of their inner workings. The Summer Coon site is appealing for analog studies, because it is unfaulted and intact, and in a semi-arid climate, so rocks are well exposed.

"We are not so much interested in eruptions," Valentine said. "It's more about what's going on underneath, because the repository will be underground. By studying an eroded volcano, we get an integrated picture of what its plumbing was like through its life."

Valentine, fellow Los Alamos geologists Frank Perry and Giday WoldeGabriel and New Mexico Tech student Emily Desmarais concentrated their sampling last summer and fall on the central area that forms



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the main conduit for magma and the hundreds of dikes radiating from the center of the volcano. These long, narrow geological features are where the hot magma flowed into cracks and cooled, forming resistant ridges harder than the surrounding or host rock.

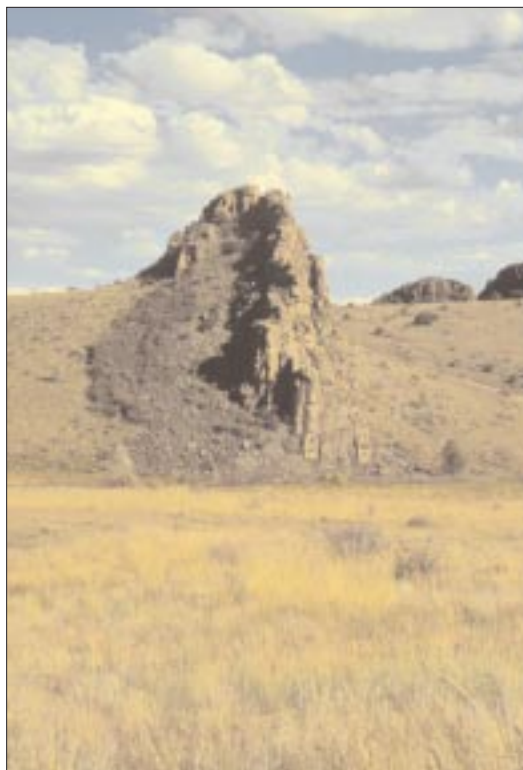
As the host rock eroded, the dikes became prominently visible. The researchers split into two teams and measured the location of dikes around half of the volcano using a global positioning system. They also measured the width of the dikes and any indication of effects on the surrounding rocks.

WoldeGabriel's task was to study the nature of hydrothermal processes, the hot fluids associated with multiple volcanic activities, such as the radial dikes at Summer Coon. The study determined the extent of hydrothermal alterations on the host rocks around the conduit in the center of the volcano, and around the various radial dikes.

"The hydrothermal processes transform the identity of the affected rocks, and most minerals are not comfortable with hot water," WoldeGabriel said. "Most rocks in the center of the volcano were transformed beyond recognition and bleached white, but we found that most hydrothermal alterations next to the radial dikes are localized and quite limited. In fact, there were no effects just 10 meters away from the dikes."

The hydrothermally altered rocks at the center of the volcano and adjacent to the dikes record at least three types of hydrothermal processes, and the team is trying to determine when these alterations took place.

Based on the data collected by counting and measuring the lengths of the dikes,



A large dike at the eroded Summer Coon volcano in the eastern foothills of the San Juan Mountains in southwestern Colorado.

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Perry developed a probability model for risk assessment using Monte Carlo simulations. The Monte Carlo method is based on taking random samples from probability distributions that, in this case, were distributions for the length and orientation of the dikes.

"We needed to calculate the probability of a radial dike entering a repository site, as a function of distance of a new volcano from the site," Perry said. "If a new volcano forms within 5 or 6 kilometers of the repository, disruption of the repository is virtually guaranteed. As the distance increases from 5 to about 15 kilometers, the probability of disruption rapidly decreases.

"There is essentially zero risk if the volcano forms at distances greater than 15 kilometers from the repository," Perry said.

These results will help Japanese scientists determine how far away a repository needs to be from volcanic clusters, which will be part of the total equation in siting a repository. That process also must take into account many socio-economic factors such as proximity to population centers in addition to others associated with the natural environment.

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LOS ALAMOS TO ASSIST IN LINAC DESIGN AND CONSTRUCTION

FIRST-OF-ITS-KIND PULSED-PROTON
ACCELERATOR GETS GO-AHEAD FROM DOE

The linear accelerator for the Spallation Neutron Source Project, currently under construction at Oak Ridge National Laboratory in Tennessee, just got smaller and perhaps less expensive to operate once it's up and running.

The SNS Project is a collaboration involving Los Alamos, E.O. Lawrence Berkeley, Argonne, Oak Ridge and Brookhaven national laboratories. (See *Dateline*, February 2000.)

Scheduled to become operational in 2005, the SNS will provide the scientific and industrial research communities worldwide with a much more intense source of neutrons than currently available for conducting neutron scattering experiments in materials science, condensed matter, magnetism and many other fields.

Recently, the Department of Energy decided to pursue a first-of-its-kind, pulsed-proton super-conducting linear accelerator, or linac, at the SNS instead of a next-generation room-temperature linac. The new superconducting

HOW DOES NEUTRON SCATTERING AFFECT OUR LIVES?

Neutron scattering is used by a variety of scientific disciplines to study the arrangement, the motion and the interaction of atoms in materials. Neutron scattering is important because it provides valuable information that often cannot be obtained using other techniques, such as optical spectroscopies, electron microscopy and X-ray diffraction. Scientists need all these techniques to provide the maximum amount of information on materials.

Although not obvious to most people, the fruits of neutron scattering research are the improvements in the range and quality of products used in our everyday lives.

Neutron scattering has been the key to obtaining basic knowledge about

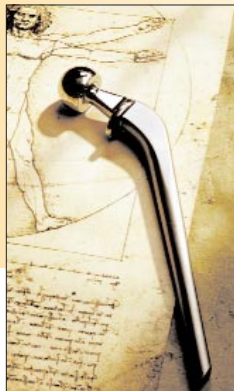
microstructures in oils and creams, including ice cream.

You can hit a golf ball farther with this driver because its head is made of an aluminum-based amorphous alloy whose special features have

been evaluated by neutron scattering.



Intense neutron beams will offer clues on preparing better surfaces of wear- and corrosion-resistant alloys for use as hip implants.





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linac will provide nominally two megawatts of beam power for producing spallation neutrons in short pulses. The more beam power, the more neutrons available for experiments. By comparison, Los Alamos' half-mile-long accelerator can provide up to 80 kilowatts of beam power for short-pulse spallation neutron production.

Shampoo is one of many complex fluids studied with neutrons whose molecular structure changes as a one-directional force is applied, making the thick liquid thin enough to spread through hair.



Neutron scattering will help scientists determine the best polymer blends to make high-quality plastic products.

The Spallation Neutron Source will enable scientists to probe small samples such as thin films for use in superconductor microwave devices for cell phone networks.

Paint must be thick enough to stick to your brush, yet thin enough when pushed to spread smoothly over a wall. How the molecular structures of a complex fluid changes



during shear thinning (e.g., by brushing paint on a wall) can be seen using neutrons.



The new accelerator's design and construction will be shared between Los Alamos and a new SNS Project partner, Jefferson Laboratory in Newport News, Va.

The superconducting linac actually is a combination of two "warm" accelerator sections and two super-conducting, or "cold," sections. Jefferson Lab has responsibility for design and construction of the superconducting niobium cavities, which are cooled to 2.1 degrees above absolute zero inside cryomodules containing liquid helium. Los Alamos, which formerly was responsible for the entire linac, retains responsibility for the following areas:

- providing room-temperature cavity physics and beam physics analyses for the entire linac;
- providing radio-frequency power, controls, diagnostics and magnets for the superconducting cavities;
- providing radio-frequency power and chopper systems (which "chop" up the beam into segments before they enter the linac) for the front end of the linac; and





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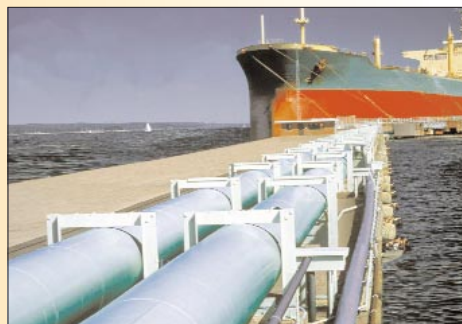
- providing and powering the high-energy beam transfer cavities at the back end of the linac.

The new linac will be just over 300 meters long, much shorter than the room-temperature linac, which would have been 465 meters long. Despite this, the superconducting linac will cost about \$15 million to \$20 million more to build. However the superconducting linac will require less electrical power to operate, so the annual operating costs could be a few million dollars less.



Los Alamos should have the engineering design for its mechanical hardware sections completed by the middle of next fiscal year. About \$30 million in SNS procurement requests will go out this fiscal year, with another \$56 million in procurement requests anticipated for next fiscal year.

Neutron scattering has been used to determine how best to manufacture and weld piping materials for use in oil pipelines to reduce residual stresses and prevent cracking and oil leaks.



Thin films that can be probed by the SNS will be used for nonvolatile memory, extending the life of laptop computer batteries.

Much of the Boeing 757 airplane is made of lightweight plastic. Neutron studies may lead to safer, faster, more energy-efficient aircraft.



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SMART SHOPPING

RECYCLED STEEL PLATES FIND USE
AT NEW LOS ALAMOS SPECTROMETER

Saving money by recycling is a good thing. Saving hundreds of thousands of dollars doing it is a really good thing.

About 300 tons of steel plates formerly used as magnet yokes for a now-decommissioned particle accelerator at E.O. Lawrence Berkeley National Laboratory will be used as shielding for Los Alamos' new Spectrometer

for Materials Research at Temperature and Stress, or SMARTS. The first load of plates arrived last month.

SMARTS is under construction at the Manuel Lujan Jr. Neutron Scattering Center. When it becomes operational, SMARTS will have the ability to perform



A technician at E.O. Lawrence Berkeley takes apart the laminated steel plates that made up the central yoke of the Bevatron accelerator. The plates are being custom cut to specifications for the SMARTS beamline at Los Alamos.

nondestructive tests on objects that vary in size from a few millimeters to that of a modest-sized jet engine.

SMARTS is one of five new world-class spectrometers being constructed at the Los Alamos Neutron Science Center as part of the Short-pulsed Spallation Source Enhancement Project. The SPSS Project is funded jointly by the Department of Energy's Office of Defense Programs and Office of Basic Energy Science.

The plates are approximately 20 feet long, three feet wide and a half-inch thick. They are bolted together in bunches of about 40 to 60, and at one time they comprised the central core of the magnet yoke in an historically important accelerator called the Bevatron.

First commissioned in February 1954, the Bevatron accelerator made major contributions in high-energy particle physics, nuclear heavy-ion physics, medical research and therapy, and space-related studies of radiation damage and heavy particles in space. The accelerator was decommissioned in February 1993.



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While the plates are slightly radioactive, their dose rates are only slightly higher than that for normal background radiation, and they therefore meet all applicable worker protection standards without the need for special handling.

Lawrence Berkeley will custom-cut the steel plates and assemble them to fit the specific design requirements of SMARTS' beam line, which is more than 100 feet long.

Compared to what it would have cost to purchase new steel plates commercially, the overall savings to the project will be about \$250,000. Lawrence Berkeley saves even more, about \$1 million, based on what it would have cost to dispose of the steel. In addition, Los Alamos may receive an additional 1,600 tons of plates from Berkeley. The Spallation Neutron Source currently under construction at Oak Ridge National Laboratory also may make use of some of the remaining tons of surplus steel plates, so the potential for all three labs to save millions of dollars is enormous.

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SCIENCE FOR THE 21ST CENTURY

ADVANCES IN THE
ACCELERATOR
TRANSMUTATION OF
NUCLEAR WASTE

In medieval times, alchemists dreamed of turning lead into gold. They never achieved that dream, but someday it may be possible to change the high-level nuclear waste produced by nuclear power plants into much more manageable wastes.

Under the U.S. Accelerator Transmutation of Waste Program, Los Alamos and other Department of Energy laboratories are studying and developing accelerator-driven technologies that can transmute such waste into more benign, stable waste forms.

About 95 percent of reactor waste is uranium that by itself does not require long-term, permanent storage. The rest is weapons-grade plutonium and other transuranics, minor actinides and high-fission products. These fission products are about one million times more hazardous than uranium.

Los Alamos has been studying ATW systems for a decade. While many potential designs for an ATW system have been examined, the main technical components remain the same: a high-power proton linear accelerator, pyrochemical spent fuel treatment/waste cleanup system and subcritical burner.

Accelerator Transmutation of Waste has the potential to reduce the amount of waste requiring permanent storage from 70,000 tons to 3,000 tons.





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It is estimated that the U.S. nuclear power industry will generate approximately 70,000 tons of high-level nuclear waste by 2015, including about 550 tons of plutonium. ATW potentially can reduce the amount of waste requiring permanent storage to less than 3,000 tons, including less than 400 pounds of plutonium. In addition, these wastes now only require a few centuries of isolation instead of 10,000 years.

Because plutonium releases energy as it is destroyed by fission in the subcritical burner, the process can power itself. Only a fraction of the energy is needed to supply the ATW system; the rest can be sold to power companies, offsetting ATW development and construction costs. Perhaps most important, destroying the weapons-grade plutonium enhances nonproliferation efforts.

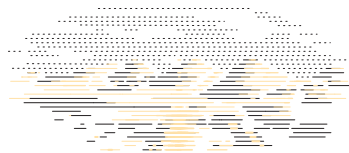
ATW begins with a spent fuel treatment center, where the uranium and short-lived fission products that cannot be transmuted are separated from the rest of the waste. These short-lived fission products are prepared for disposal, while the uranium can be recycled for reuse or prepared for disposal.

The remaining transuranics, minor actinides and long-lived fission products are transferred to the subcritical burner, where virtually most are destroyed by fission or transmuted into more benign, short-lived waste forms by neutrons produced by the accelerator's proton beam as it strikes the burner's spallation target inside. The linear accelerator at Los Alamos is the most powerful in the world and conceivably can drive several subcritical burners at once.

Los Alamos, in collaboration with eight other DOE laboratories, recently developed a five-year "road map" for ATW research and development, which includes examining all available technology development options, developing a prototype test facility and demonstrating key aspects of the technologies.

Los Alamos plans to conduct some of those demonstrations. While an ATW facility may be years away, its potential for solving a worldwide environmental dilemma is undeniable.

SCIENCE FOR THE 21ST CENTURY



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BRIEFLY ...

You're receiving May's *Dateline* late because of the Lab closure during the Cerro Grande Fire. Two weeks ago (as I write this) I was glued to a television in Santa Fe, where my family had evacuated early that morning, watching "my" town burn. As I watched in disbelief as the homes of family, friends and co-workers went up in flames, I wondered if any of us would have homes — or jobs — to return to. And here I am, two weeks later, back at my computer, trying to return to normal. Mother Nature humbles us. We pride ourselves on our ability to conduct great science, yet the force of a forest fire makes us aware that there are so many things we can't control and don't understand. I am awestruck at the devastation and how close my town came to losing everything. My heart goes out to the more than 400 Los Alamos families who lost their homes. And I will be forever grateful to the firefighters and other people who put their lives on the line to save Los Alamos, the Laboratory and Northern New Mexico.

— Meredith Coonley, editor

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